Assimilating Data into a Circulation Model

H. Tuba Özkan-Haller
College of Oceanic and Atmospheric Sciences
Oregon State University
104 Ocean Admin Bldg
Corvallis, OR 97331-5503
phone: (541) 737-9170 fax: (541) 737-2064 email: ozkan@coas.oregonstate.edu

Award Number: N00014-02-1-0198

Jennifer Shore
Civil and Environmental Engineering and Geodetic Science
Ohio State University
470 Hitchcock Hall, 2700 Neil Ave
Columbus, OH 43210-1275
phone: (614) 247-6051 fax: (614) 292-4697 email: shore.13@osu.edu

Award Number: N00014-02-1-0212

Thomas C. Lippmann
Civil and Environmental Engineering and Geodetic Science
Ohio State University
Byrd Polar Research Center, 1090 Carmack Road
Columbus, OH 43210-1002
phone: (614) 688-0080 fax: (614) 292-4697 email: lippmann.2@osu.edu

Award Number: N000140210238

James M. Kaihatu
Ocean Dynamics and Prediction Branch
Oceanography Division
Naval Research Laboratory
Stennis Space Center, MS 39529-5004
phone: (228) 688-5710 fax: (228) 688-4759 email: kaihatu@nrlssc.navy.mil

Award Number: N0001403WX20018
http://science.whoi.edu/users/pvlab/NCEX/index.html

LONG-TERM GOALS

The long-term goal of this study is to build an integrated circulation observation/prediction system where a variety of remote and in situ field observations can be assimilated into a numerical model to provide near real-time nowcasting and forecasting capabilities in the nearshore.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Assimilating Data into a Circulation Model**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,,College of Oceanic and Atmospheric Sciences,,104 Ocean Admin Bldg,,Corvallis,,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

OBJECTIVES

Our objective is to construct an integrated modeling capability that will rely on advancements in both models and spatially dense measurements of nearshore currents. The system consists of an existing numerical model of the depth- and phase-averaged equations of motion governing the temporal and spatial evolution of the nearshore circulation (Özkan-Haller and Kirby, 1999), and will utilize observations of surface current patterns obtained using Particle Image Velocimetry (PIV) techniques applied to a video system (PI's Lippmann and Holland) as well as other remotely obtained data such as surf zone width or proxies for radiation stress gradients (PI Holman). Our focus is on a thorough understanding of the assimilation techniques and the implementation into the circulation model, and testing of the modeling scheme as part of the Nearshore Canyon Experiment (NCEX) planned for the fall of 2003 (see http://science.whoi.edu/users/pvlab/NCEX/index.html). Our specific objectives are to:

- Adapt an existing nearshore circulation model based on the depth- and phase-averaged nonlinear equations of motions (Özkan-Haller and Kirby, 1999) to incorporate (assimilate) observations of currents. Test resulting model with synthetic and existing data.

- Test the assimilation techniques with field data obtained by collaborating groups as part of NCEX. This work will begin on-site during the experiment, and continue in the subsequent year following its conclusion.

- Develop and implement methods of data assimilation that will aid in the incorporation of non-traditional measurements that can be obtained from surf zone video observations, such as surf zone width and energy dissipation.

APPROACH

Data assimilation methods provide a formal means for combining models with measurements to generate solutions that constitute a best fit to all relevant data while satisfying the constraints imposed by the modeling equations. Our focus is on the thorough understanding of the assimilation techniques and their implementation into the circulation model and testing of the modeling scheme as part of the NCEX field experiment. . Two distinct strategies are being examined:

1. The first strategy involves computationally efficient sequential estimators that correct forward model output using available data, but do not tune model parameters (such as frictional coefficients). We anticipate being able to model a "strip" of the beach that extends alongshore for several kilometers and is bounded by the shoreline and the 10 m contour in the cross-shore direction (see Figure 1).

2. The second strategy involves more computationally expensive inverse models that are used to adjust free model parameters to achieve an optimal fit to the data. Inverse methods are based on the derivation of an adjoint model, which propagates information backwards in both space and time. The forward and adjoint models are coupled and are solved iteratively. This process is outlined schematically in Figure 2. Using this technique we anticipate modeling a portion of the NCEX site, such as the area around Black's beach, in detail.

WORK COMPLETED

We have been working on several fronts. First, we have carried out simulations of the wave field in the NCEX region utilizing several wave propagation models (REF/DIF 1, STWAVE, SWAN, and REF/DIF S) and are carrying out intercomparisons as well as comparisons with estimates of the wave angle obtained by Holman and his group using Argus images of the region. Secondly, in order to make on-site computations during the field experiment possible we have revised the existing circulation code to increase its numerical efficiency. We are now capable of modeling the circulation over an approximately 4km alongshore width centered around the Black's Beach region in real time. Our results indicate location, strength, and time variability of the circulation in this region, Secondly, in relation to the development of an inverse model we have derived and implemented an adjoint model for the nearshore circulation model. We have applied this variational data assimilation technique to the prediction of longshore currents on alongshore uniform bathymetry. Utilizing simulated data, we found that the magnitude of the bottom shear stress can be accurately predicted even in situations where significant physics (such as roller effects or alongshore non-uniformities) are neglected by the adjoint model. Encouraged by these results we are now researching alternate and more efficient solution methods to the coupled forward and adjoint problem for use in two-dimensional problems.

RESULTS

We have carried out simulations for several wave climates expected during the early fall. An example of our results for the wave field and resulting circulation are given in Figures 1 and 2, respectively, for the case of narrow banded northerly swell. The wave field indicates wave focusing to the north and south of the Scripps canyon with low wave height near the tup of the canyon. The resulting circulation field is highly time-variable and displays a rip current in the middle of the Black's beach region that is relatively stationary is location but can undulate significantly in time.

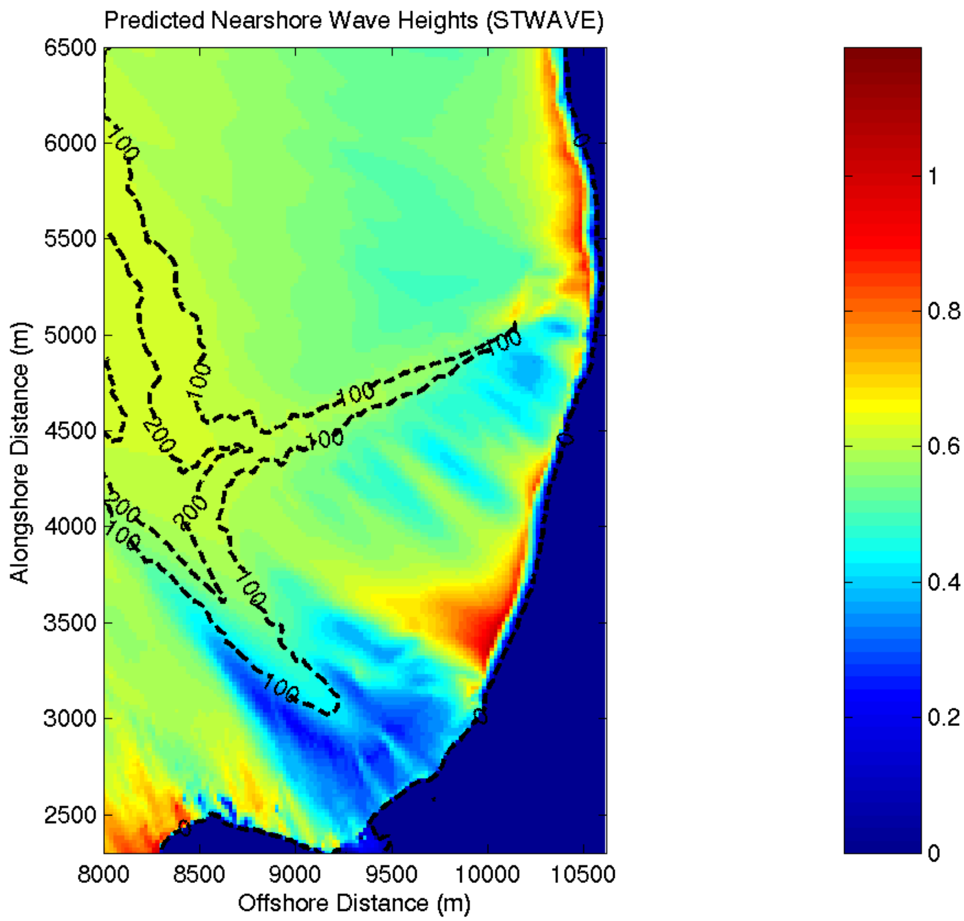

Figure 1: Wave height over an area around the NCEX experimental site for northerly swell conditions. Wave focusing can be observed to the north and south of each canyon with low wave heights to the tips of the canyons.

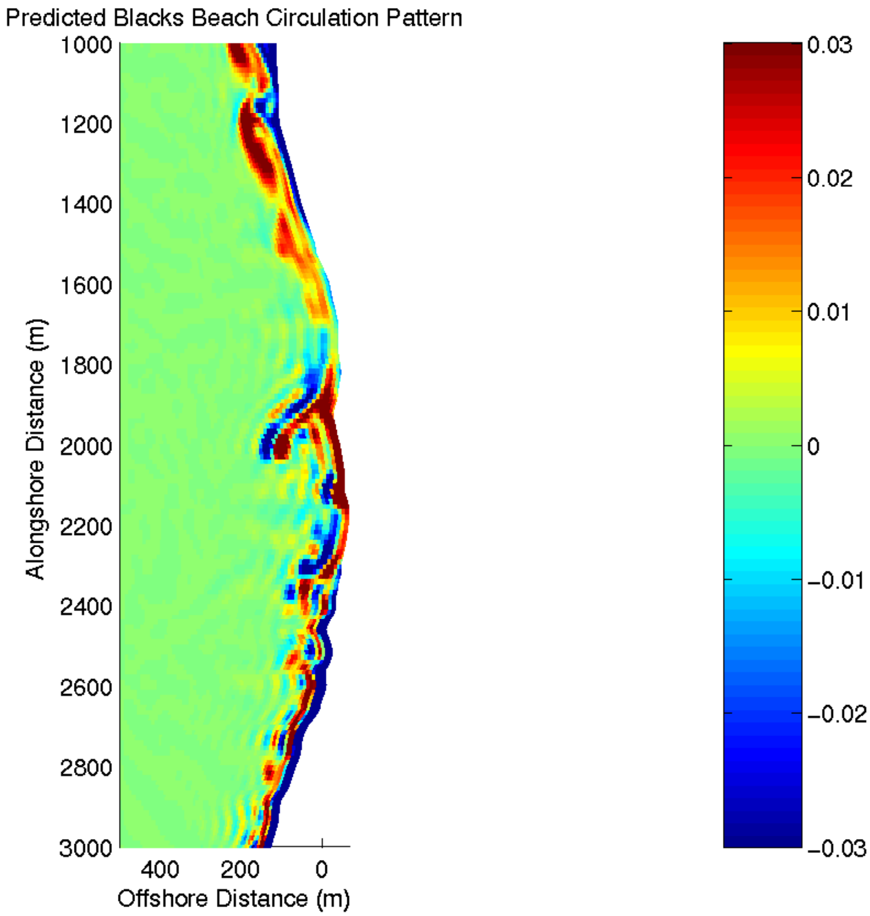

Figure 2: Vorticity field associated with the circulation at Black's Beach. A rip current that is relatively stationary in location can be observed to undulate by analyzing several snapshots. A northward longshore current exists north of Black's Beach and undulations in this current can also be observed.

Starting about mid-October the modeling system will be executed daily on site at the NCEX experiment, and comparisons will be made to observations of the wave and circulation field using video observations by Lippmann and Holman and their groups as part of separate ONR projects.

Within the last year we have also made progress in deriving and implementing a variational data assimilation procedure for nearshore circulation and applied this solution to the prediction of alongshore current on planar beaches. For testing purposes we generate simulated data by running the forward model with an assumed friction coefficient (which is allowed to be a function of space). We then sample the generated longshore current at a few locations ("current meter locations") and feed this artificial data into our adjoint modeling scheme. The resulting predictions allow us to backtrack the size and spatial distribution of the friction coefficient. We find that we can successfully predict this quantity provided the alongshore current is strong enough to provide guidance (v >~0.2 m/s) (see Figure 3). We also find that the magnitude of the friction coefficient can be estimated well even in situations where significant physics (such as roller effects and alongshore non-uniformities) are neglected by the adjoint model.

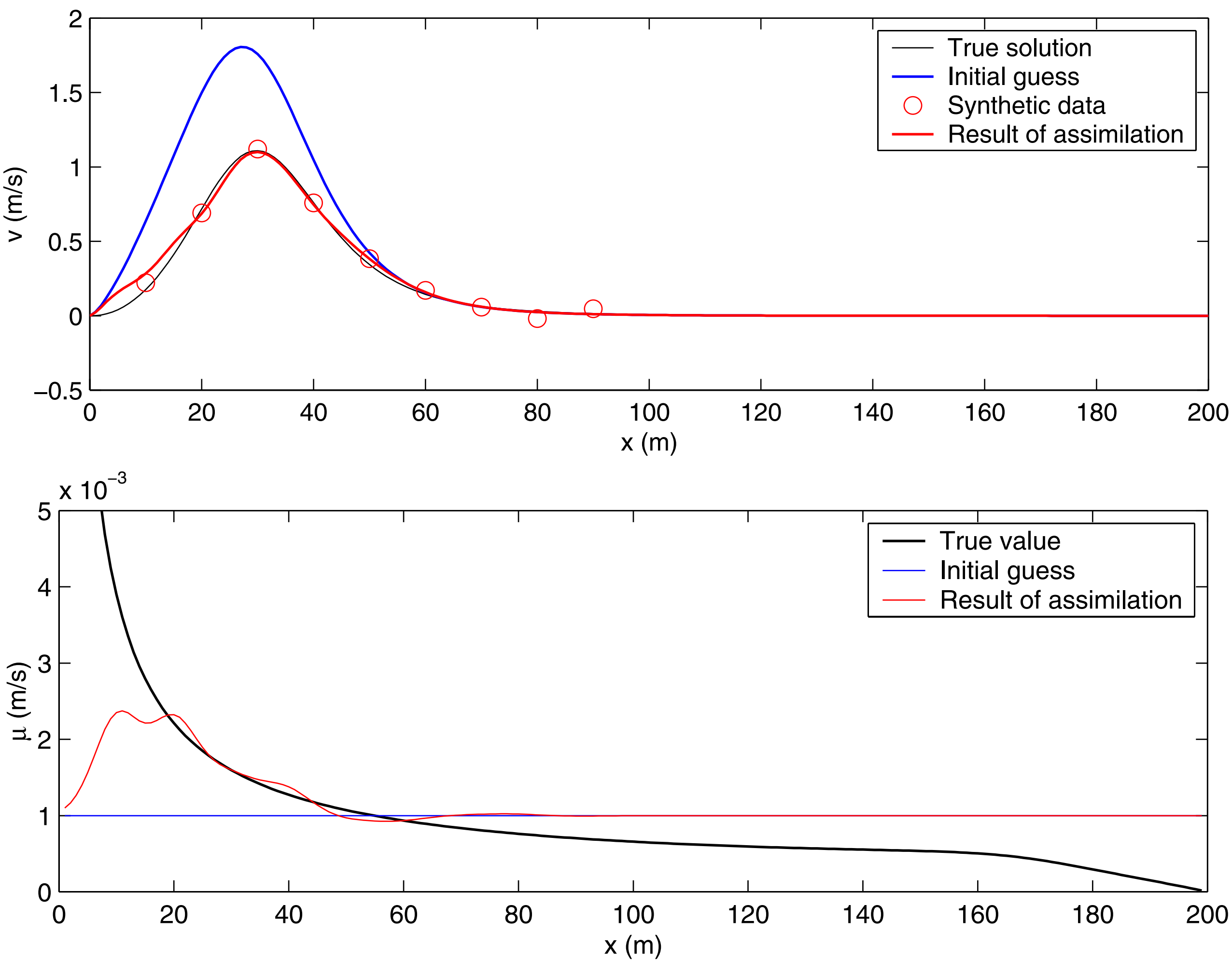

Figure 3: (upper panel) Longshore velocity as a function of cross-shore location. Shown are the true solution (black), the synthetic data (open circles), initial guess (blue) and result of assimilating the synthetic data (red). (lower panel) True value of the frictional coefficient (black), initial guess (blue) and result of the assimilation (red).

IMPACT/APPLICATIONS

This study will further our understanding of assimilation techniques and their application in the neashore region, particularly in relation to spatially non-uniform and possibly discontinuous data sets. The model development undertaken here will increase the scientific understanding of the circulation in the nearshore and will also pave the way to operational models for nowcasting and forecasting in the nearshore region.

TRANSITIONS

The work on the project will lead to a robust modeling tool, which is capable of predicting the time-varying circulation field in the nearshore region. The model code will be available to the engineering

and science communities. The resulting model can at a later date be transitioned to allow for operational use in hindcasting, nowcasting and ultimately forcasting circulation in the nearshore region.

RELATED PROJECTS

This effort is part of an overall program related to the Nearshore Canyon Experiment (NCEX) planned off the coast of CA in the Fall of 2003. Close collaborations are planned with other researchers involved in NCEX-related projects. Also, knowledge gained about the assimilation methods used here can benefit the ongoing NOPP project (Lead P.I. J.T. Kirby) “Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean”.